TSUNAMI GLOSSARY

INTERNATIONAL TSUNAMI INFORMATION CENTER (ITIC)
INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)
International Co-ordination Group for the Tsunami Warning System in the Pacific
(ICG/ITSU)

1. TSUNAMI CLASSIFICATION

Characteristics of the Tsunami Phenomena

A tsunami travels outward from the source region as a series of waves. Its speed depends upon the depth of the water, and consequently the waves undergo accelerations or decelerations in passing respectively over an ocean bottom of increasing or decreasing depth. By this process the direction of wave propagation also changes, and the wave energy can become focused or defocused. In the deep ocean, tsunami waves can travel at speeds of 500 to 1,000 kilometers per hour. Near shore, however, a tsunami slows down to just a few tens of kilometers per hour. The height of a tsunami also depends upon the water depth. A tsunami that is just a meter in height in the deep ocean can grow to tens of meters at the shoreline. Unlike familiar wind-driven ocean waves that are only a disturbance of the sea surface, the tsunami wave energy extends to the ocean bottom. Near shore, this energy is concentrated in the vertical direction by the reduction in water depth, and in the horizontal direction by a shortening of the wavelength due to the wave slowing down.

Tsunamis have periods (the time for a single wave cycle) that may range from just a few minutes to as much as an hour or exceptionally more. At the shore, a tsunami can have a wide variety of expressions depending on the size and period of the waves, the near-shore bathymetry and shape of the coastline, the state of the tide, and other factors. In some cases a tsunami may only induce a relatively benign flooding of low-lying coastal areas, coming onshore similar to a rapidly rising tide. In other cases it can come onshore as a bore - a vertical wall of turbulent water that can be very destructive. In most cases there is also a drawdown of sea level preceding crests of the tsunami waves that results in a receding of the shoreline, sometimes by a kilometer or more. Strong and unusual ocean currents may also accompany even small tsunamis.

Destruction from tsunamis is the direct result of three factors: inundation, wave impact on structures, and erosion. Strong tsunami-induced currents have led to the erosion of foundations and the collapse of bridges and seawalls. Flotation and drag forces have moved houses and overturned railroad cars. Tsunami associated wave forces have demolished frame buildings and other structures. Considerable damage also is caused by the resultant floating debris, including boats and cars that become dangerous projectiles that may crash into buildings, piers, and other vehicles. Ships and port facilities have been damaged by surge action caused by even weak tsunamis. Fires resulting from oil spills or combustion from damaged ships in port, or from ruptured coastal oil storage and refinery facilities, can cause damage greater than that inflicted directly by the tsunami. Other secondary damage can result from sewage and chemical pollution following the destruction. Damage of intake, discharge, and storage facilities also can present dangerous problems. Of increasing concern is the potential effect of tsunami drawdown, when receding waters uncover cooling water intakes associated with nuclear plants.

air-coupled tsunami Synonym for atmospheric tsunami.

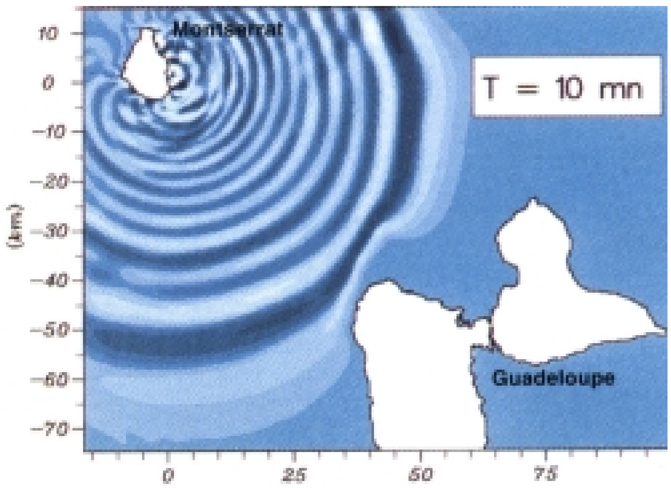
atmospheric tsunami Tsunami-like waves generated by a rapidly moving atmospheric pressure front moving over a shallow sea at about the same speed as the waves, allowing them to couple.

internal tsunami Tsunami wave manifested as an internal wave and traveling along a thermocline.

local tsunami A tsunami which its destructive effects are confined to coasts within a hundred km, of the source, usually an earthquake and sometimes a landslide.

microtsunami A tsunami of such small amplitude that it must be observed instrumentally and is not easily detected visually.

near-field or local tsunami A tsunami from a nearby source, generally less than 200 km away. A local tsunami is generated by a small earthquake, a landslide or a pyroclastic flow.



Numerical Modeling: snapshots of the water surfaces 10 minutes after the initiation of the submarine landslide of the pyroclastic flow (on the South-East part of Monserrat Island)

Pacific-wide tsunami A tsunami capable of widespread destruction, not only in the immediate region of its generation, but across the entire Pacific Ocean.

1960 Damaged caused by the May 22, 1960 Chilean Tsunami

paleotsunami Research on paleotsunamis, events occurring prior to the historical record, has recently been taking place in a few regions around the Pacific. This work is based primarily on the collection and analysis of tsunami deposits found in coastal areas, and other evidence related to the uplift or subsidence associated with nearby earthquakes. In one instance, the research has led to a new concern for the possible future occurrence of great earthquakes and tsunamis along the northwest coast of North America. In another instance, the record of tsunamis in the Kuril-Kamchatka region is being extended much further back in time. As work in this field continues it may provide a significant amount of new information about past tsunamis to aid in the assessment of the tsunami hazard.

regional tsunami A tsunami capable of destruction in a particular geographic region, generally within about 1000 km of its source. Regional tsunamis also occasionally have very limited and localized effects outside the region.

Most destructive tsunami can be classified as ***local*** or ***regional***, meaning their destructive effects are confined to coasts within a hundred km, or up to a thousand km, respectively, of the source -- usually an earthquake. It follows that the majority of tsunami related casualties and property damage also come from local tsunami. Between 1975 and 1998 there have been at least eighteen in the Pacific and its adjacent seas resulting in significant casualties and/or property damage.

Table of Recent local and regional tsunamis

Date			*Source Location*	*Estimated Lives Lost*
29	Nov	1975	Hawaii, USA	2
17	Aug	1976	Philippines	*8,000
19	Aug	1977	Indonesia	189
18	Jul	1979	Indonesia	540
12	Sep	1979	New Guinea	100
12	Dec	1979	Colombia	500
26	May	1983	Sea of Japan	100
2	Sep	1992	Nicaragua	168
12	Dec	1992	Flores Is., Indonesia	1,000
12	Jul	1993	Okushiri Is., Japan	230
3	Jun	1994	Java, Indonesia	222
4	Oct	1994	Shikotan Is., Russia	11
14	Nov	1994	Philippines	74
9	Oct	1995	Manzanillo, Mexico	1
1	Jan	1996	Sulawesi, Indonesia	9
17	Feb	1996	Irian Jaya, Indonesia	110
23	Feb	1996	Peru	12
17	July	1998	Papua New Guinea	2,500

* May include earthquake casualties

For example, a regional tsunami in 1983 in the Sea of Japan or East Sea, severely damaged coastal areas of Japan, Korea, and Russia, causing more than $800 million in damage, and more than a hundred deaths. Then, after nine years without an event, eleven locally destructive tsunamis occurred in just a seven-year period from 1992 to 1998, resulting in over 4,200 deaths and hundreds of millions of dollars in property damage. In most of these cases, tsunami mitigation efforts in place at the time were unable to prevent significant damage and loss of life. However, losses from future local or regional tsunamis can be reduced if a denser network of warning centers, seismic and water-level reporting stations, and better communications are established to provide a timely warning, and if better programs of tsunami preparedness and education can be put in place.

teletsunami or distant tsunami A tsunami originating from a distant source, generally more than 1000 km away.

Far less frequent, but potentially much more hazardous are ***Pacific-wide*** or ***distant*** tsunamis. These occur when the disturbance that generates the tsunami is sufficiently great. Usually starting as a local tsunami that causes extensive destruction near the source, these waves continue to travel across the entire ocean basin with sufficient energy to cause additional casualties and destruction on shores more than a thousand km from the source. In the last two hundred years, there have been at least seventeen destructive Pacific-wide tsunamis.

The most destructive Pacific-wide tsunami of recent history was generated by a massive earthquake off the coast of Chile on May 22, 1960. All Chilean coastal towns between the 36th and 44th parallels were either destroyed or heavily damaged by the action of the tsunami and the quake. The combined tsunami and earthquake toll included 2,000 killed, 3,000 injured, 2,000,000 homeless, and $550 million damage. Off the coastal town of Corral, Chile, the waves were estimated to be 20 meters (67 feet) high. The tsunami caused 61 deaths in Hawaii, 20 in the Philippines, and 100 or more in Japan. Estimated damages were US$50 million in Japan, US$24 million in Hawaii and several more millions along the west coast of the United States and Canada. Distant wave heights varied from slight oscillations in some areas to 12 meters (40 feet) at Pitcairn Island; 11 meters at Hilo, Hawaii; and 6 meters at some places in Japan.

A Pacific-wide tsunami today, similar in size to the May 1960 event, could easily have catastrophic consequences.

Table of Major Pacific Teletsunamis

Date			*Source Location*	*Estimated Lives Lost*
20	Feb	1835	Chile	2
7	Nov	1837	Chile	62
13	Aug	1868	Chile	*25,000
10	May	1877	Chile	500
15	June	1896	Sanriku, Japan	22,000
31	Jan	1906	Colombia-Ecuador	500
17	Aug	1906	Chile	-
7	Sep	1918	Kuril Is., Russia	47
11	Nov	1922	Chile	100
3	Feb	1923	Kamchatka, Russia	2
2	Mar	1933	Sanriku, Japan	3,000
1	Apr	1946	Aleutian Is., U.S.A.	179
4	Nov	1952	Russia	-
9	Mar	1957	Aleutian Is., U.S.A.	5
22	**May**	**1960**	**Chile**	**2,000**
28	Mar	1964	Alaska, U.S.A.	112
4	Feb	1965	Aleutian Is., U.S.A.	-

*May include earthquake casualties

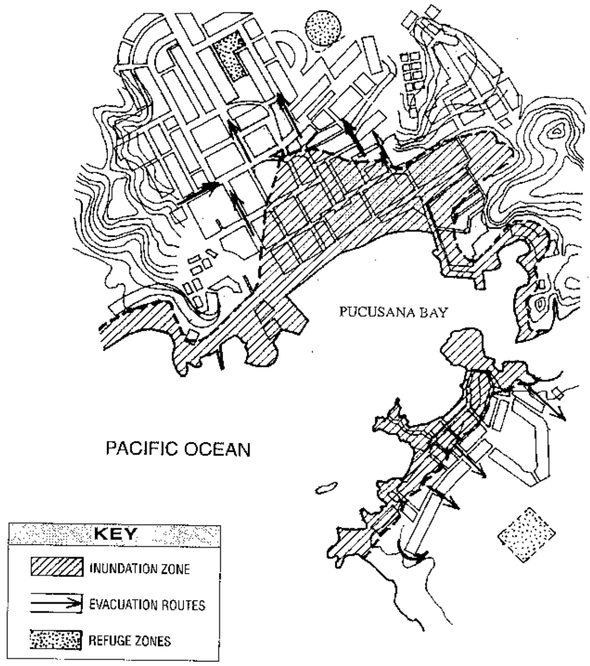
tsunami earthquake An earthquake that produces an unusually large tsunami relative to the earthquake magnitude (Kanamori, 1972). Tsunami earthquakes are characterized by a very shallow focus, fault dislocations greater than several meters, and fault surfaces smaller than for normal earthquakes. They are also slow earthquakes, with slippage along their faults occurring more slowly than would occur in normal earthquakes. The last events of this type were 1992 Nicaragua and 1996 Chimbote, Peru.

2. GENERAL TSUNAMI TERMS

This section contains the general terms on tsunami mitigation (such as tsunami damage, tsunami hazard) and on tsunami modeling and generation.

estimated time of arrival (ETA) Time of tsunami arrival at some fixed location, as estimated from modeling the speed and refraction of the tsunami waves as they travel from the source. ETA is estimated with very good precision if the bathymetry and source are well known (less than a couple of minutes)

evacuation map A drawing or representation that outlines danger zones and designates limits beyond which people must be evacuated to avoid harm from tsunami waves.



Inundation and Evacuation Map created for the coastal town of Pucusana, Peru.

historical tsunami data Historical data are available in many forms and at many locations. The forms include published and manuscript catalogs of tsunami occurrences, marigraphs, tsunami amplitude, run-up and inundation zone measurements, field investigate reports, newspaper accounts, film or video records.

hydraulic model A physical scale model of a basin or a harbor used to simulate effects of wave action or flooding caused by hurricane surge or tsunami wave activity.

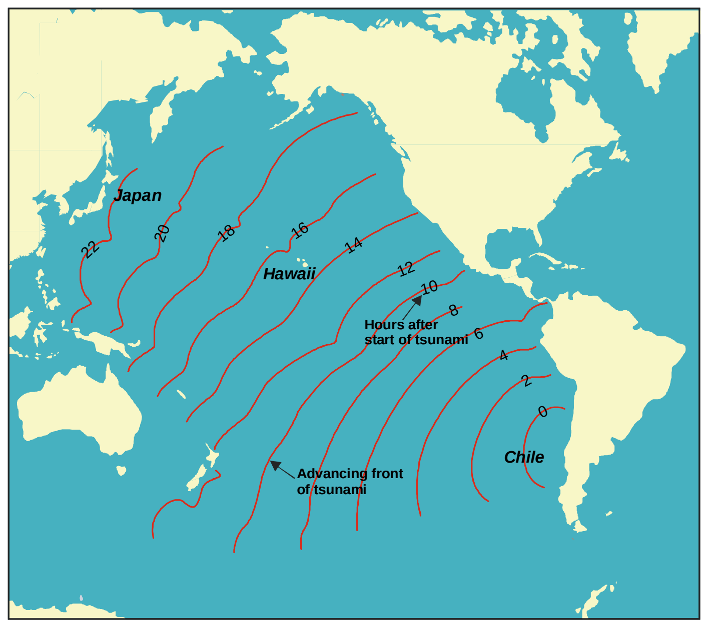
hydraulic modeling Mathematical formulations used in connection with a hydraulic physical model to simulate natural hydrologic phenomena which are considered as processes or as systems.

post-tsunami survey Tsunamis are relatively rare events and most of their evidence is perishable. Therefore, it is very important that reconnaissance surveys be organized and carried out quickly and thoroughly after each tsunami occurs, to collect detailed data valuable for hazard assessment, model validation, and other aspects of tsunami mitigation.

In recent years, following each major destructive tsunami, a post-tsunami reconnaissance survey has been organized to make measurements of runups and inundation limits and to collect associated data from eyewitnesses such as the number of waves, arrival time of waves, and which wave was the largest. The surveys have been organized primarily on an ad-hoc basis by academic tsunami researchers, with participants often gathered from several of the ITSU Member States. A *Post-Tsunami Survey Field Guide* (http://www.shoa.cl/oceano/itic/field.html) has been prepared by ITSU to help with preparations for surveys, to identify measurements and observations that should be taken, and to standardize data collection methods for increased consistency and accuracy.

travel time Time required for the first tsunami wave to propagate from its source to a given point on a coastline.

travel time map Map showing isochrons or lines of equal tsunami travel time calculated from the source outwards toward terminal points on distant coastlines.



Travel-times (in hours) for the May 22, 1960 Chile tsunami crossing the Pacific basin. This tsunami was extremely destructive along the nearby coast of Chile, and the tsunami also caused significant destruction and casualties as far away as Hawaii and Japan. The awareness and concern raised by this Pacific-wide tsunami ultimately led to the formation of the TWSP and ITSU.

tsunami A series of traveling waves of extremely long length and period, usually generated by disturbances associated with earthquakes occurring below or near the ocean floor. (Also called seismic sea wave and, popularly, tidal wave.) Also, a series of ocean waves produced by a submarine earthquake, landslide, or volcanic eruption. These waves may reach enormous dimensions and travel across entire ocean basins with little lost of energy. They proceed as ordinary gravity waves with a typical period between 5 and 60 minutes. Tsunamis steepen and increase in height on approaching shallow water, inundating low-lying areas; and where local submarine topography causes extreme steeping, they may break and cause great damage. Tsunamis have no connection with tides; the popular name is entirely misleading.

Destruction along the waterfront of Hilo, Hawaii from the Pacific-wide tsunami generated off the coast of Unimak Island, Aleutian, USA on April 1, 1946

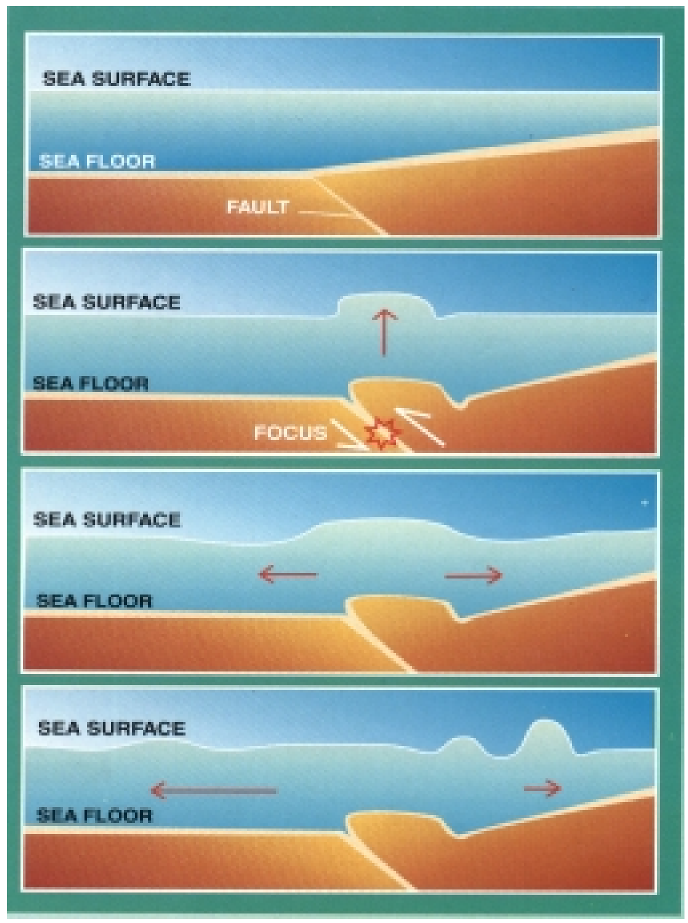
tsunami damage Loss or harm caused by a destructive tsunami. More specifically, the damage caused direc-

Massive destruction in the town of Aonae on Okushiri Island, Japan caused by the regional tsunami of July 12, 1993.

tly by tsunamis can be summarized into the following: 1) deaths and injuries; 2) houses destroyed, partly destroyed, inundated, flooded, or burned; 3) other property damage and loss; 4) boats washed away, damaged or destroyed; 5) lumber washed away; 6) marine installations destroyed, and; 7) damage to public utilities such as railroads, roads, electric power plants, water supply installations, etc. Indirect secondary tsunami damage can be: 1) Damage by fire of houses, boats, oil tanks, gas stations, and other facilities; 2) environmental pollution caused by drifting materials, oil, or other substances; 3) outbreak of disease of epidemic proportions which could be serious in densely populated areas.

tsunami dispersion Redistribution of tsunami energy, particularly as a function of its period, as it travels across a body of water.

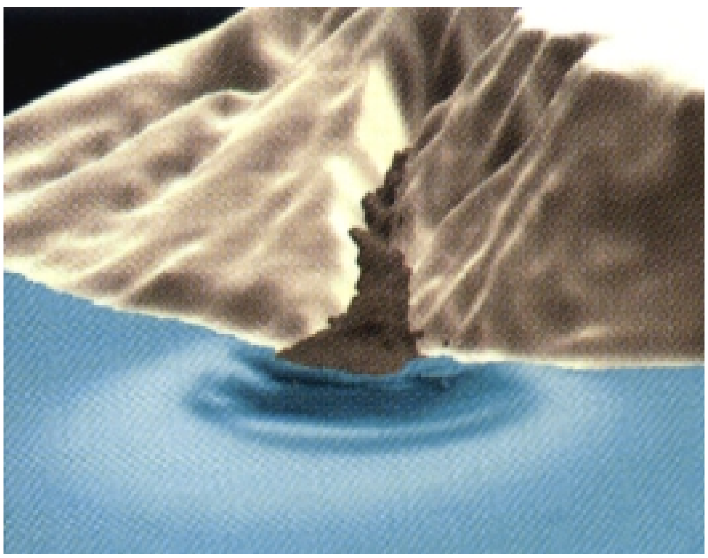
tsunami generation Tsunamis are generated primarily by tectonic dislocations under the sea which are



Tsunami generated by an earthquake

caused by shallow focus earthquakes along areas of subduction. The upthrusted and downthrusted crustal blocks impart potential energy into the overlying water mass with drastic changes in the sea level over the affected region. The energy imparted into the water mass results in tsunami generation which is energy radiating away from the source region in the form of long period waves.

Tsunami generated by a landslide



Tsunami generated by a pyroclastic flow

tsunami generation theory The theoretical problem of generation of the gravity wave (tsunami) in the layer of elastic liquid (an ocean) occurring on the surface of elastic solid half-space (the crust) in the gravity field can be studied with methods developed in the dynamic theory of elasticity. The source representing an earthquake focus is a discontinuity in the tangent component of the displacement on some element of area within the crust. For conditions representative of the Earth's oceans, the solution of the problem differs very little from the joint solution of two more simple problems: the problem of generation of the displacement field by the given source in the solid elastic half-space with the free boundary (the bottom) considered quasi-static and the problem of the propagation of gravity wave in the layer of heavy incompressible liquid generated by the known (from the solution of the previous problem) motion of the solid bottom. There is the theoretical dependence of the gravity wave parameters on the source parameters (depth and orientation). In particular, a very rough estimation of the source energy passing into the gravity wave can be obtained. In general, a portion of it corresponds to the estimates obtained with empirical data. Also, tsunamis can be generated by other different mechanisms such as volcanic or nuclear explosions, landslides, rock falls and submarine slumps.

tsunami hazard The probability of that a tsunami of a particular size will strike a particular section of coast.

Tsunami Hazard

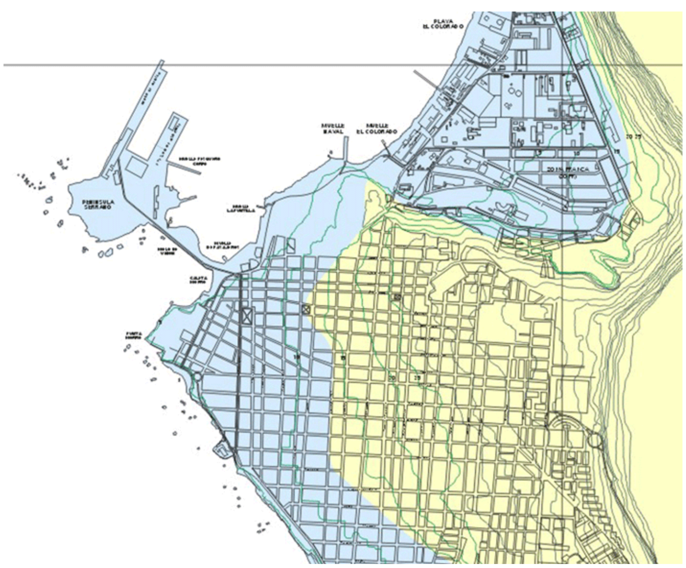
There are tens of thousands of kilometers of coastline in the Pacific region, representing portions of at least 23 countries around the rim, and 21 island states. These areas are developing at an accelerating rate with the expansion of harbor and industrial facilities in most locations, and increasing population densities almost everywhere. This element of growth in both population and infrastructure development exposes more people and their homes, buildings, and transportation systems to the onslaught of tsunamis. Since 1992, major local tsunamis have claimed more than 4,200 lives and caused hundreds of millions of dollars in property damage.

tsunami hazard assessment For each coastal community, an assessment of the tsunami hazard is needed to identify populations and assets at risk, and the level of that risk. This assessment requires knowledge of probable tsunami sources (such as earthquakes, landslides, volcanic eruption), their likelihood of occurrence, and the characteristics of tsunamis from those sources at different places along the coast. For those communities, data of earlier (historical and paleotsunamis) tsunamis may help quantify these factors. For most communities, however, only very limited or no past data exist. For these coasts, numerical models of tsunami inundation can provide estimates of areas that will be flooded in the event of a local or distant tsunamigenic earthquake, local landslide.

tsunami impact Although infrequent, tsunamis are among the most terrifying and complex physical phenomena and have been responsible for great loss of life and extensive destruction to property. Because of their destructiveness, tsunamis have important impacts on the human, social and economic sectors of societies. Historical records show that enormous destruction of coastal communities throughout the world has taken place and that the socio-economic impact of tsunamis in the past has been enormous. In the Pacific Ocean where the majority of these waves have been generated, the historic record shows tremendous destruction with extensive loss of life and property.

In Japan, which has one of the most populated coastal regions in the world and a long history of earthquake activity, tsunamis have destroyed entire coastal populations. There is also a history of severe tsunami destruction in Alaska, the Hawaiian Islands, and South America, although records for these areas are not as extensive. The last major Pacific-wide tsunami occurred in 1960. Many other local and regional destructive tsunamis have occurred with more localized effects.

tsunami numerical modeling Often the only way to determine the potential runups and inundation from a local or distant tsunami is to use numerical modeling, since data from past tsunamis is usually insufficient. Models can be initialized with potential worst case scenarios for the tsunami sources or for the waves just offshore to determine corresponding worst case scenarios for runup and inundation. Models can also be initialized with smaller sources to understand the severity of the hazard for the less extreme but more frequent events. This information is then the basis for creating tsunami evacuation maps and procedures. At present, such modeling has only been carried out for a small fraction of the coastal areas at risk. Sufficiently accurate modeling techniques have only been available in recent years, and these models require training to understand and use correctly, as well as input of detailed bathymetric and topographic data in the area being modeled.



Estimated Tsunami Inundation at Iquique-Chile, based on numerical model results.

Numerical models have been used in recent years to simulate tsunami propagation and interaction with land masses. Such models usually solve similar equations but often employ different numerical techniques and are applied to different segments of the total problem of tsunami propagation from generation regions to distant areas of runup.

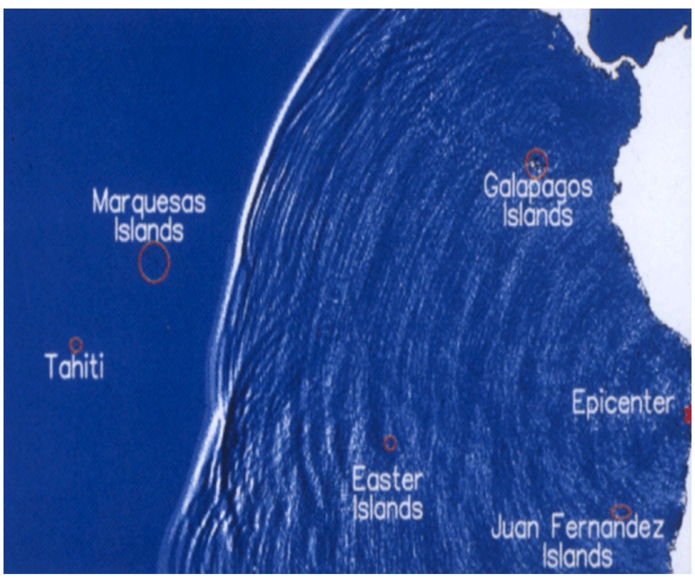
For example, several numerical models have been used to simulate the interaction of tsunamis with islands. These models have used finite difference, finite element, and boundary integral methods to solve the linear long wave equations. These models solve these relatively simple equations and provide reasonable simulations of tsunamis for engineering purposes.

Historical data are very limited for most Pacific coastlines. Consequently, numerical modeling may be the only way to estimate the potential risk to those areas from the tsunami hazard. Techniques now exist to carry out this assessment. Computer programs and training necessary to perform this modeling need to be transferred to all Pacific countries at risk through programs such as the IOC/ITSU Tsunami Inundation Modeling Exchange.

tsunami observation Notice, observation or measurement of sea level fluctuation at a particular point in time caused by the incidence of a tsunami on a specific point.

tsunami preparedness Readiness of plans, methods, procedures and actions taken by government officials and the general public for the purpose of minimizing potential risk and mitigating the effects of future tsunamis. The appropriate preparedness for a warning of impending danger from a tsunami requires knowledge of areas that could be flooded (tsunami inundation maps) and knowledge of the warning system to know when to evacuate and when it is safe to return.

tsunami propagation Tsunamis travel outward in all directions from the generating area, with the direction of the main energy propagation generally being orthogonal to the direction of the earthquake fracture zone. Their speed depends on the depth of water, so that the waves undergo accelerations and decelerations in passing over an ocean bottom of varying depth. In the deep and open ocean, they travel at speeds of 500 to 1,000 kilometers per hour (300 to 600 miles per hour). The distance between successive crests can be as much as 500 to 650 kilometers (300 to 400 miles); however, in the open ocean, the height of the waves is generally less than a meter (3 feet) even for the most destructive teletsunamis, and the waves pass unnoticed. Variations in tsunami propagation result when the propagation impulse is stronger in one direction than in others because of the orientation or dimensions of the generating area and where regional bathymetric and topographic features modify both the wave form and rate of advance. Specifically tsunami waves undergo a process of wave refraction and reflection throughout their travel. Tsunamis are unique in that the waveform extends through the entire water column from sea surface to the ocean bottom. It is this characteristic that accounts for the great amount of energy propagated by a tsunami.



Model of the tsunami propagation in the southeast Pacific, nine hours after its generation. Source: Antofagasta, Chile (30 July, 1995)

tsunami risk The probability of a particular coastline being struck by a tsunami times what is exposed to tsunami damaged and casualties along that coast. In general terms, risk is the hazard times the exposure.

tsunami source Point or area of tsunami origin, usually the site of an earthquake, volcanic eruption, or landslide that caused large-scale rapid displacement of the water to initiate the tsunami waves.

tsunamic Having features analogous to those of a tsunami or descriptive of a tsunami.

tsunamigenic Having generated a tsunami: a tsunamigenic earthquake, a tsunamigenic landslide.

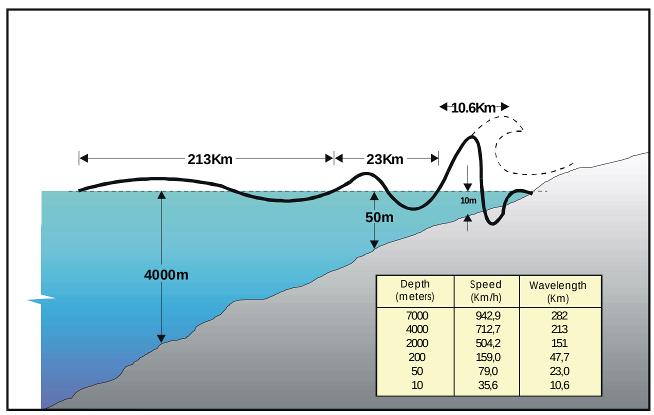
tsunami velocity or shallow water velocity The velocity of an ocean wave whose length is sufficiently large compared to the water depth (i.e., 25 or more times the depth) can be approximated by the following expression:

$$c = \mathrm{Sqrt}(gh)$$

Where:
c is the wave velocity
g the acceleration of gravity
h the water depth.

Thus, the velocity of shallow-water waves is independent of wave length L. In water depths between ½ L and 1/25 L it is necessary to use a more precise expression:

$$c = \mathrm{Sqrt}(\,(gL/2\pi)[\tanh(2\,\pi\, h/L)])$$



Depth (meters)	Speed (Km/h)	Wavelength (Km)
7000	942,9	282
4000	712,7	213
2000	504,2	151
200	159,0	47,7
50	79,0	23,0
10	35,6	10,6

Wave Height and Water Depth: in the open ocean a tsunami is less than a few feet high at the surface, but its wave height increases rapidly in shallow water. Tsunami wave energy extends from the surface to the bottom in the deepest waters. As the tsunami attacks the coastline, the wave energy is compressed into am much shorter distance creating destructive, life threatening waves.

tsunami zonation (tsunami zoning) Designation of distinctive zones along coastal areas with varying degrees of tsunami risk and vulnerability for the purpose of disaster preparedness, planning, construction codes, or public evacuation.

3. SURVEYS AND MEASUREMENTS

All the terms and parameters that measured the tsunami waves on mareograph (such as tsunami amplitude, tsunami period) and measured in the field during a survey (such as run-up, maximum horizontal inundation, inundation line) and to classify a tsunami (tsunami magnitude).

arrival time Time of the first maximum of the tsunami waves.

crest length The length of a wave along its crest. Sometimes called crest width.

drop The downward change or depression in sea level associated with a tsunami, a tide, or some long term climatic effect.

elapsed time Time between the maximum level arrival time and the arrival time of the first wave.

horizontal inundation Distance between the inundation line and the shore, generally measured perpendicularly to the shore.

initial rise Time of the first minimum of the tsunami waves.

intensity Extreme strength, force or energy.

inundation area Area flooded with water by the tsunami

inundation line Inland limit of wetting, measured horizontally from the mean sea level (MSL) line. The vegetation line is sometimes used as a reference. If it can be determined that it is more than 10 feet from the MSL line, adjust; otherwise, ignore. In tsunami science, the landward limit of tsunami runup.

leading wave First arriving wave of a tsunami. In some cases, the leading wave produces an initial depression or drop in water level, and in some cases an elevation or rise in water level.

magnitude A number assigned to a quantity by means of which the quantity may be compared with other quantities of the same class.

maximum inundation Maximum horizontal penetration of the tsunami from the shoreline. A maximum inundation is measured for each different coast or harbor affected by the tsunami.

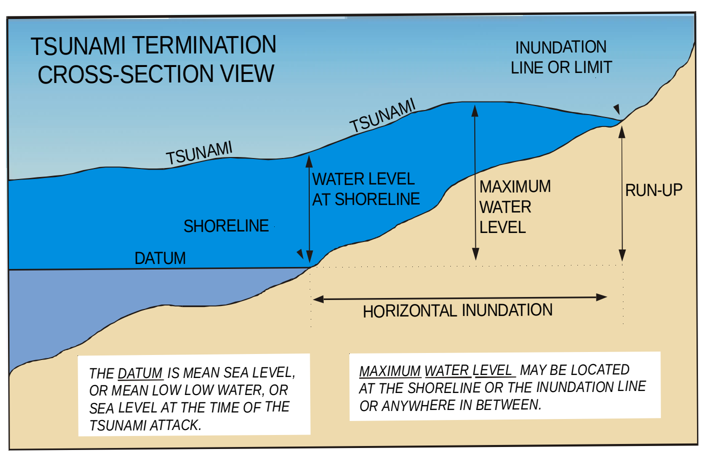
maximum run-up Maximum difference between the elevation at the maximum tsunami penetration (the inundation line) and sea-level at the time of the tsunami attack. A maximum run-up is measured for each different coast or harbor affected by the tsunami.

mean height Average height of a tsunami measured from the trough to the crest after removing the tidal variation.

overflow A flowing over, inundation.

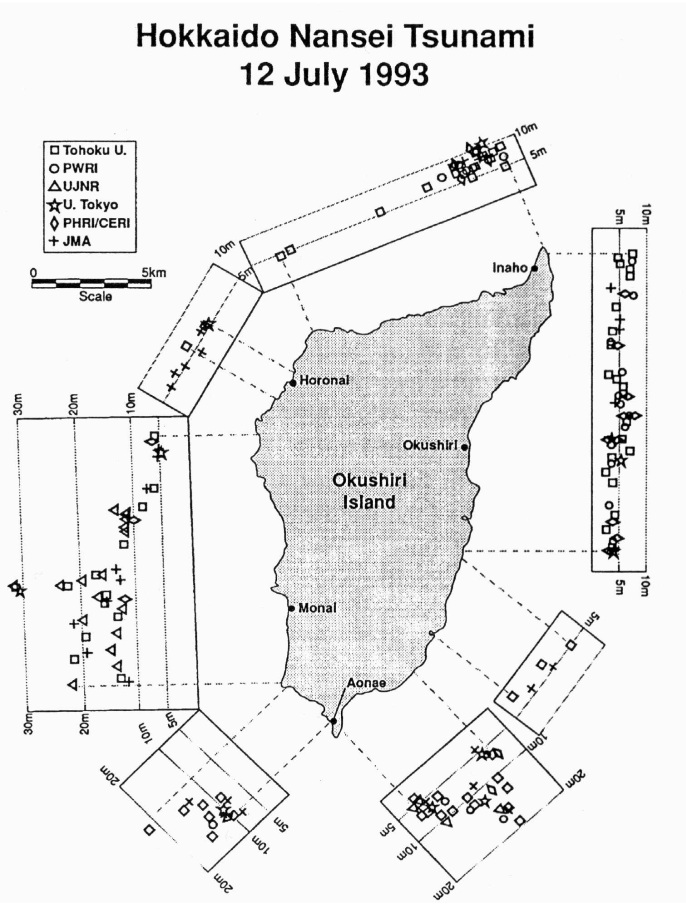
rise The upward change or elevation in sea level associated with a tsunami, a hurricane, a tide, or some long term climatic effect.

run-up 1. Difference between the elevation of maximum tsunami penetration (inundation line) and the sea-level at the time of the tsunami attack. **2.** Elevation reached by seawater measured relative to some stated datum such as mean sea level, mean low water, sea level at the time of the tsunami attack, etc., and measured ideally at a point that is a local maximum of the horizontal inundation. **3.** In practical terms, run-up is only measured where there is a clear evidence of the inundation limit on the shore.



Tsunami termination cross-section view

run-up distribution Set of tsunami runup values measured or observed along a coastline.



Run-up measured during the Hokkaido Nansei Tsunami of July, 12, 1993.

Sieberg tsunami intensity scale A descriptive tsunami intensity scale which was later modified into the Sieberg-Ambraseys tsunami intensity scale described below (Ambraseys 1962).

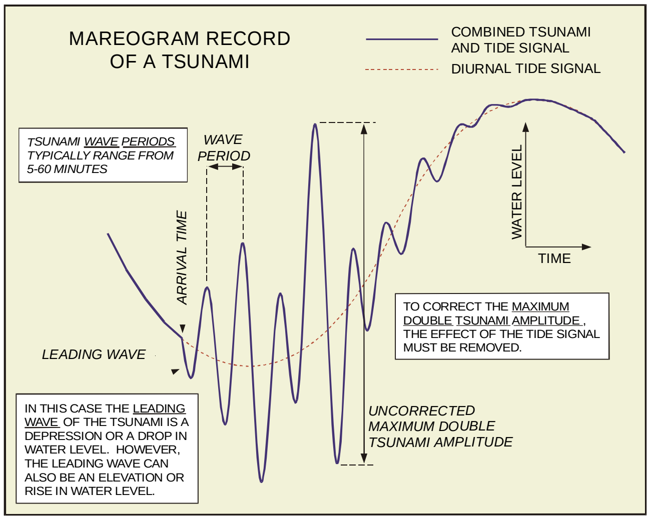
<u>**Modified Sieberg Sea-wave Intensity Scale**</u>

1. Very light. Wave so weak as to be perceptible only on tide-gauge records.
2. Light. Wave noticed by those living along the shore and familiar with the sea. On very flat shores generally noticed
3. Rather strong. Generally noticed. Flooding of gently sloping coasts. Light sailing vessels carried away on shore. Slight damage to light structures situated near the coasts. In estuaries reversal of the river flow some distance upstream.
4. Strong. Flooding of the shore to some depth. Light scouring on man-made ground. Embankments and dikes damaged. Light structures near the coasts damaged. Solid structures on the coast injured. Bid sailing vessels and small ships drifted inland or carried out to sea. Coasts littered with floating debris.
5. Very strong. General flooding of the shore to some depth. Quay-walls and solid structures near the sea damaged. Light structures destroyed. Severe scouring of cultivated land and littering of the coast with floating items and sea animals. With the exception of big ships all other type of vessels carried inland or out to sea. Big bores in estuary rivers. Harbor works damaged. People drowned. Wave accompanied by strong roar.
6. Disastrous. Partial or complete destruction of man-made structures for some distance from the shore. Flooding of coasts to great depths. Big ships severely damaged. Trees uprooted or broken. Many casualties.

significant wave height The average height of the one-third highest waves of a given wave group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, the average height of the highest one-third of a selected number of waves, this number being determined by dividing the time of record by the significant period. Also characteristic wave height.

spreading When reference is made to tsunami waves, it is the spreading of the wave energy over a wider geographical area as the waves propagate away from the source region. The reason for this geographical spreading and reduction of wave energy with distance traveled, is the sphericity of the earth. The tsunami energy will begin converging again at a distance of 90 degrees from the source. Of course tsunami waves propagating across a large ocean undergo other changes in energy configuration due to refraction, primarily, but geographical spreading is also very important depending upon the orientation, dimensions and geometry of the tsunami source.

tsunami amplitude Usually measured on a water level record, it is: **1.** the absolute value of the difference between a particular peak or trough of the tsunami and the undisturbed water level at the time, **2.** half the difference between an adjacent peak and trough, corrected for the change of tide between that peak and trough. It is intended to represent the true amplitude of the tsunami wave at some point in the ocean. However, it is often an amplitude modified in some way by the response of the tide gauge.



Mareogram record of a tsunami

tsunami amplitude (maximum) Usually measured on a water level record, it is half the value of the maximum peak-to-trough excursion, corrected for the change of tide between that peak and trough.

tsunami magnitude Mt Measurement of the overall physical size of a tsunami, defined in terms of instrumental tsunami-wave amplitudes. Tsunami magnitude is defined by:

$$Mt = \log 2H$$

as revised by Iida, Cox, and Pararas-Carayannis (1967), where H is the maximum run-up height or amplitude on a coastline near the generating area. Other tsunami magnitude scales have been proposed, also based on maximum run-up height. Abe defined two different tsunami magnitude amplitudes. His first tsunami magnitude (1979) is:

$$Mt = \log H + B$$

where H is the maximum single crest or trough amplitude of the tsunami waves (in meters) and B a constant. The second definition (1981) is:

$$Mt = \log H + a \log R + D$$

where R is the distance in km from the earthquake epicenter to the tide station along the shortest oceanic path, and a and D are constants.

tsunami period Amount of time that a tsunami wave takes to complete a cycle. Tsunami periods typically range from 5 minutes to 2 hours.

tsunami period (dominant) Difference between the arrival time of the highest peak and the next one measured on a water level record.

tsunami wave length The horizontal distance between similar points on two successive waves measured perpendicularly to the crest. The wave length and the tsunami period give an information on the tsunami source. For tsunami generated by earthquakes, typical wave length range from 20 to 300 km. For tsunami generated by landslide, the wave length range from hundreds of meters to tens of kilometers.

water level (maximum) Difference between the elevation of the highest local water mark and the elevation of the sea-level at the time of the tsunami attack. This is different from maximum run-up because the water mark is often not observed at the inundation line, but maybe halfway up the side of a building or on a tree trunk.

wave crest 1. The highest part of a wave. **2.** That part of the wave above still water level.

4. TIDE, MAREOGRAPH, SEA LEVEL

All the terms relative to the sea level, the tide measurement and the mareograph.

breaker A sea-surface wave that has become so steep (wave steepness of 1/7) that the crest outraces the body of the wave and it collapses into a turbulent mass on shore or over a reef. Breaking usually occurs when the water depth is less than 1.28 times the wave height. Roughly, three kinds of breakers can be distinguished, depending primarily on the gradient of the bottom: (a) spilling breakers (over nearly flat bottom) which form a foamy patch at the crest and break gradually over a considerable distance; (b) plunging breakers (over fairly steep bottom gradient) which peak up, curl over with a tremendous overhanging mass and then break with a crash; (c) surging breakers (over very steep bottom gradients) which do not spill or plunge but surge up the beach face. Waves also break in deep water if they build too high while being generated by the wind, but these are usually short-crested and are termed whitecaps.

breakwater An offshore structure such as a wall that is used to protect a harbor or beach from the force of waves.

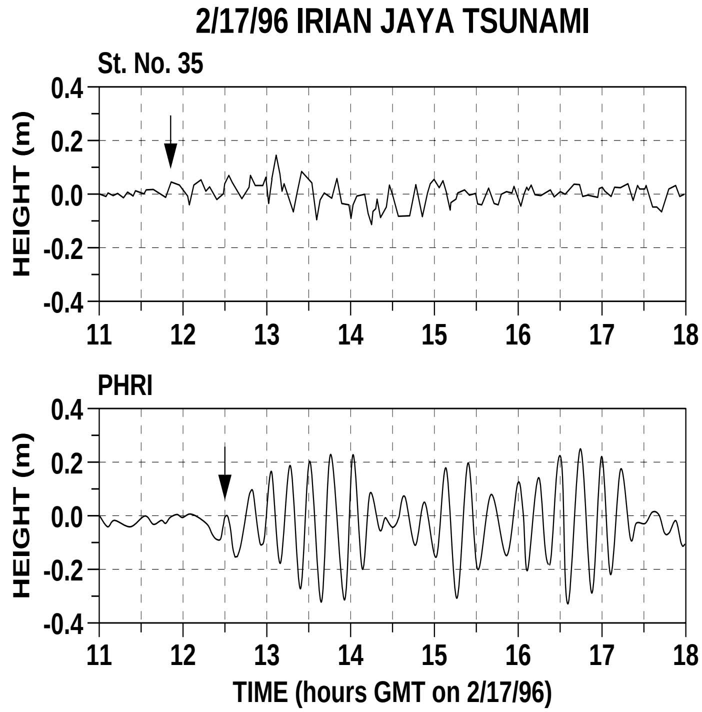
1995 Chilean Tsunami: An observation of the tsunami effects behind the breakwater at Tahauku Bay in the Marquesas Islands, French Polynesia, several thousand kilometers away from the tsunami source.

cotidal Indicating equality with the tides or a coincidence with the time of high or low tide.

eddy By analogy with a molecule, a "glob" of fluid within the fluid mass that has a certain integrity and life history of its own; the activities of the bulk fluid being the net result of the motion of the eddies.

low water The lowest water level reached during a tide cycle. The accepted popular term is low tide.

mareogram or marigram 1. Record made by a marigraph. **2.** Any graphic representation of the rise and fall of the sea level, with time as abscissa and height as ordinate, usually used to measured tides, may also show tsunamis.



Mareograms of tsunami signals measured by an underwater gauge located 50 km outside the entrance to Tokyo Bay in about 50 m of water (upper trace), and another gauge located at the shore (lower trace). The tsunami is detected on the outside gauge about 40 minutes before it reaches shore (arrows). The offshore gauge was developed by Japan's Port and Harbours Research Institute.

mareograph A recording tide gauge.

mean sea level The average height of the sea surface, based upon hourly observation of tide height on the open coast or in adjacent waters which have free access to the sea. These observations are to have been made over a "considerable" period of time. In the United States, mean sea level is defined as the average height of the surface of the sea for all stages of the tide over a nineteen-year period. Selected values of mean sea level serve as the sea level datum for all elevation surveys in the United States. Along with mean high water, mean low water, and mean lower low water, mean sea level is a type of tidal datum.

probable maximum water level A hypothetical water level (exclusive of wave runup from normal wind-generated waves) that might result from the most severe combination of hydrometeorological, geoseismic and other geophysical factors that is considered reasonably possible in the region involved, with each of these factors considered as affecting the locality in a maximum manner. This level represents the physical response of a body of water to maximum applied phenomena such as hurricanes, moving squall lines, other cyclonic meteorological events, tsunamis, and astronomical tide combined with maximum probable ambient hydrological conditions such as wave level with virtually no risk of being exceeded.

reference sea level The observed elevation differences between geodetic bench marks are processed through least-squares adjustments to determine orthometric heights referred to a common vertical reference surface, which is the reference sea level. In this way, height values of all bench marks in the vertical control portion of a surveying agency are made consistent and can be compared directly to determine differences of elevation between bench marks in a geodetic reference system that may not be directly connected by lines of geodetic leveling. The vertical reference surface in use in the United States, as in most parts of the world, approximates the geoid. The geoid was assumed to be coincident with local mean sea level at 26 tidal stations to obtain the Sea Level Datum of 1929 (SLD 290). National Geodetic Vertical Datum of 1929 (NGVD 29) became a name change only; the same vertical reference system has been in use in the United States since 1929. This important vertical geodetic control system is made possible by a universally accepted, reference sea level.

sea level The height of the sea at a given time measured relative to some datum, such as mean sea level

tidal wave 1. The wave motion of the tides. **2.** In popular usage, any unusually high and therefore destructive water level along a shore. It usually refers to either a storm surge or tsunami.

tide The rhythmic, alternate rise and fall of the surface (or water level) of the ocean, and of bodies of water connected with the ocean such as estuaries and gulfs, occurring twice a day over most of the Earth, and resulting from the gravitational attraction of the moon (and, in lesser degrees, of the sun) acting unequally on different parts of the rotating Earth.

tide amplitude One-half of the difference in height between consecutive high water and low water; hence, half of the tidal range.

tide gauge A device for measuring the height (rise and fall) of the tide. Especially an instrument for automatically making a continuous graphic record of tide height versus time.

Picture of a Chilean Tide Gauge installed on a pier at Coquimbo bay (latitude 30º South) showing the water-proof case, the solar panel, the flat antenna and the pressure sensor.

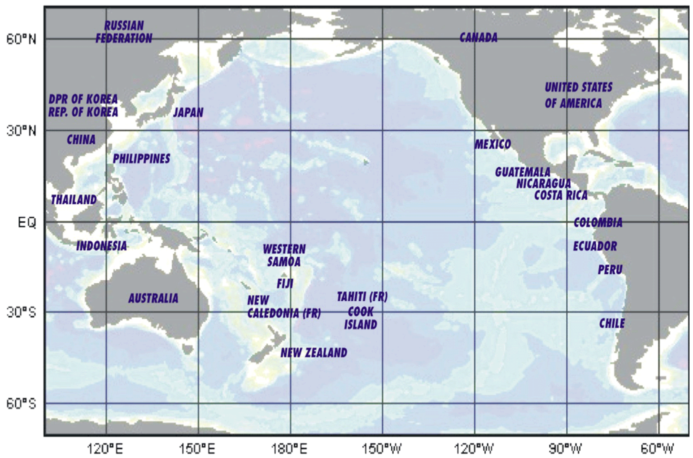
tide station A place where tide observations are obtained.

5. ACRONYMS & ITSU ORGANIZATION

The ICG/ITSU define several acronyms of its organizatin, the bodies created by IOC (ITIC, PTWC), and the different bulletins and publications.

Communications Plan for the Tsunami Warning System in the Pacific Operations manual for the Tsunami Warning System in the Pacific. The Plan lists the tidal and seismological stations which participate in the warning system, preferred methods of communications between the stations and the Pacific Tsunami Warning Center (PTWC), and criteria for reporting. The Plan also lists recipients of tsunami watch and warning messages and methods by which the messages are sent. The Plan also provides a general overview of the operational procedures of the Tsunami Warning System and of the nature of tsunamis.

ICG/ITSU International Coordination Group for the Tsunami Warning System in the Pacific. ICG/ITSU is an international organization for promoting cooperation and coordination of tsunami mitigation activities. It was established in 1965 as a subsidiary body of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, and is composed of national representatives from Member States in the Pacific Region. It meets every two years to review progress and coordinate activities resulting in improvements to the Tsunami Warning System. There are currently 25 Member States: Australia, Canada, Chile, China, Colombia, Cook Islands, Costa Rica, Democratic People's Republic of Korea, Ecuador, Fiji, France, Guatemala, Indonesia, Japan, Mexico, New Zealand, Nicaragua, Peru, Philippines, Republic of Korea, Singapore, Thailand, Federation of Russia, United States of America., and Western Samoa.



ITSU member states

IOC Intergovernmental Oceanographic Commission of UNESCO. *(http://ioc.unesco.org/iocweb/default.htm)*

ITIC International Tsunami Information Center. Established in 1968 by the IOC, ITIC works closely with the Pacific Tsunami Warning Center (PTWC). Located in Honolulu, Hawaii, ITIC is responsible, among other functions for: monitoring the international tsunami warning activities in the Pacific and recommending improvements with regard to communications, data networks, data acquisition, and information dissemination; bringing to Members and non-members information on tsunami warning systems, on affairs of ITIC and on how to become active participants in the activities of ITSU; assisting Member States of ITSU establishment of national warning systems and improving preparedness for tsunamis for all nations throughout the Pacific Ocean; gathering and promulgating knowledge about tsunamis and fostering tsunami research and its application to prevent loss of life and damage to property. *(http://www.shoa.cl/oceano/itic/frontpage.html)*

ITSU International Coordination Group for the Tsunami Warning System in the Pacific (a shortening of International TSUnami).

IUGG International Union of Geodesy and Geophysics.

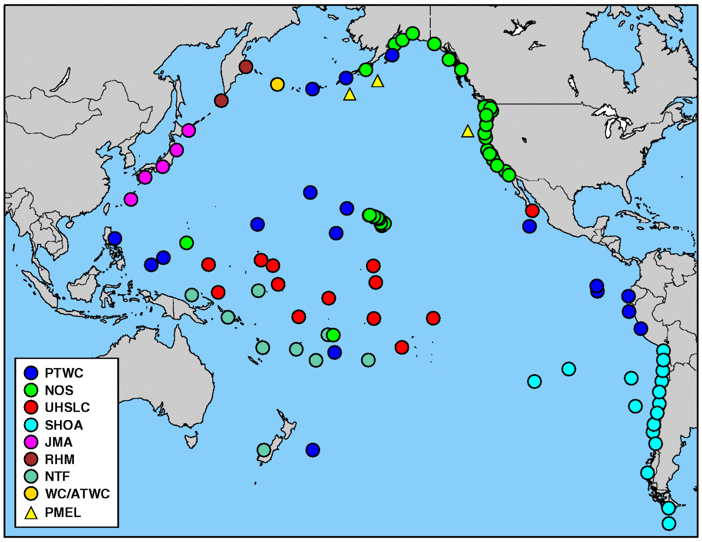
Master Plan The principal plan which outlines the methods and procedures that need to be followed in order to accomplish the long term goals of a program. The first edition of the ICG/ITSU Master Plan was released in 1989. The second edition was released in 2000. *(http://www.shoa.cl/oceano/itic/Master.html)*

PTWC Pacific Tsunami Warning Center. PTWC is the headquarters of the operational Tsunami Warning System (TWS) in the Pacific and works closely with other regional national centers in monitoring seismological and tidal stations and instruments around the Pacific Ocean, to evaluate potentially tsunamigenic earthquakes. PTWC is operated by the United States National Weather Service. *(http://www.nws.noaa.gov/pr/ptwc)*

Operations area of the Pacific Tsunami Warning Center in Ewa Beach, Hawaii.

PTWC facilities located at Ewa Beach, Hawaii, USA.

PTWS Pacific Tsunami Warning System. PTWS is the operational Tsunami Warning System in the Pacific.



Tsunami Warning System Sea Level Gauges

Tsunami Bulletin Board Email exchange system primarily for tsunami scientists that is used to quickly disseminate ideas and information regarding tsunamis and tsunami research. The Tsunami Bulletin Board has been very useful for helping to rapidly organize post-tsunami surveys and distribute their results, and to plan tsunami workshops and symposia.

Tsunami Information Bulletin Message issued by PTWC to advise participants of the occurrence of a major earthquake in the Pacific or near-Pacific area, with the evaluation that a potentially destructive Pacific-wide tsunami was not generated.

Tsunami Warning Bulletin Warning message issued throughout the Pacific based on confirmation that a tsunami has been generated that poses a threat to the population in part or all of the Pacific. A Tsunami Warning will be followed by additional bulletins with updated information until it is cancelled.

Regional Tsunami Warning/Watch Bulletin Message issued initially by PTWC based only on seismic information to alert all participants of the possibility of a tsunami and advise them that a tsunami investigation is underway. Those areas that are within 0 to 3 hours from the estimated time of arrival of the first wave are placed in a Tsunami Warning status. Those areas within 3 to 6 hours are placed in a Tsunami Watch status. It will be followed by additional bulletins until it is either upgraded to a Pacific-wide Tsunami Warning or until it is cancelled. The following is an example of a Regional Warning/Watch Bulletin issued by the PTWC.

TSUNAMI BULLETIN NUMBER 001
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS
ISSUED 13 JAN, 1808 UTC

THIS BULLETIN IS FOR ALL AREAS OF THE PACIFIC BASIN EXCEPT CALIFORNIA, OREGON, WASHINGTON, BRITISH COLUMBIA, AND ALASKA.

. . . A TSUNAMI WARNING AND WATCH ARE IN EFFECT . . .

A TSUNAMI WARNING IS IN EFFECT FOR:
NICARAGUA, EL SALVADOR, MEXICO
A TSUNAMI WATCH IS IN EFFECT FOR:
ECUADOR, PANAMA, PERU

FOR OTHER AREAS IN THE PACIFIC, THIS MESSAGE IS FOR INFORMATION ONLY.

AN EARTHQUAKE, PRELIMINARY MAGNITUDE 7.7, OCCURRED 13 JAN, 1733 UTC.
COORDINATES: LATITUDE 13.1 NORTH,
LONGITUDE 88.6 WEST
VICINITY: OFF COAST OF CENTRAL AMERICA.

EVALUATION: IT IS NOT KNOWN THAT A TSUNAMI WAS GENERATED.

THIS WARNING AND WATCH ARE BASED ONLY ON EARTHQUAKE EVALUATION.

ESTIMATED TIMES OF INITIAL WAVE ARRIVAL AT LOCATIONS WITHIN THE WARNING AND WATCH AREAS ARE:

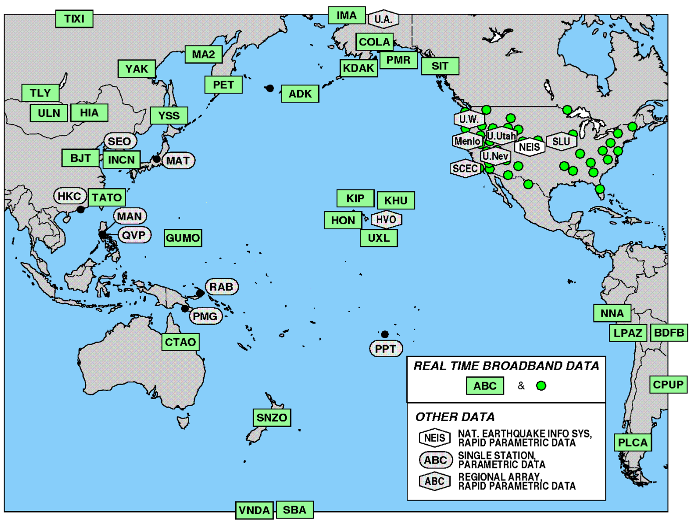
NICARAGUA	CORINTO	1946Z 13 JAN
	PUERTO SANDINO	1947Z 13 JAN
	SAN JUAN DL SUR	2025Z 13 JAN
EL SALVADOR	ACAJUTLA	1955Z 13 JAN
MEXICO	ACAPULCO	2034Z 13 JAN
	MANZANILLO	2133Z 13 JAN
	SOCORRO	2219Z 13 JAN
ECUADOR	BALTRA IS.	2115Z 13 JAN
PANAMA	BALBOA HTS.	2247Z 13 JAN
PERU	LA PUNTA	2343Z 13 JAN

BULLETINS WILL BE ISSUED HOURLY OR SOONER IF CONDITIONS WARRANT.

THE TSUNAMI WARNING WILL REMAIN IN EFFECT UNTIL FURTHER NOTICE.

RECIPIENTS OF THIS MESSAGE LOCATED IN CALIFORNIA, OREGON, WASHINGTON, BRITISH COLUMBIA, AND ALASKA SHOULD REFER ONLY TO ALASKA TSUNAMI WARNING CENTER MESSAGES FOR INFORMATION ABOUT ANY TSUNAMI THREAT IN THOSE AREAS.

TWSP Tsunami Warning System in the Pacific.



Seismic data used by PTWC in support of the TWSP

Tsunami warning systems in the Pacific can be classified by two related factors: 1) the type of tsunami they are prepared to warn against - from local to distant, and 2) the area of responsibility (AOR) they warn for each type of tsunami - sub-national, national, regional, or international. The **Pacific-wide system** operated by PTWC provides an international warning about one-half to one hour after the occurrence of the earthquake, and is effective for communities located at least several hundred kilometers from the source region. **Regional systems**, such as those operated by the USA, Japan, the Russian Federation, France, and Chile, provide primarily domestic warnings within about 10-15 minutes of the earthquake and are effective for communities located at least a hundred kilometers from the source region. **Local systems** operated by Japan, Chile and United States of America are capable of providing a warning in about 5 minutes or less to give some measure of protection to communities located within a hundred kilometers of the source. Just as important as issuing warnings, are issuing rapid cancellations to warnings when no significant waves are found to exist, and informational messages for large but not potentially tsunamigenic earthquakes.

Centers that operate the tsunami warning systems include: the Pacific Tsunami Warning Center at Ewa Beach, Hawaii, USA; the West Coast / Alaska Tsunami Warning Center at Palmer, Alaska, USA; the Russian Federation tsunami warning centers at Petropavlovsk-Kamchatskiy, Kurilskiye, and Sakhalinsk; the Japanese tsunami warning centers at Sapporo, Sendai, Tokyo, Osaka, Fukuoka, and Naha; the French Polynesia Tsunami Warning Center at Papeete, Tahiti, and the National Tsunami Warning System of Chile headquartered at Valparaiso.

Certain other Member States have also recently established or improved their seismic and/or water level instrumentation and analysis capabilities as the basis for national tsunami warning systems.

UNESCO United Nations Educational, Scientific and Cultural Organization.

WDC World Data Center.

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INTERNATIONAL
TSUNAMI
INFORMATION
CENTER
(ITIC)

http://www.shoa.cl/oceano/itic/frontpage.html

Located in Honolulu, the **International Tsunami Information Center (ITIC)** was established on 12 November 1965 by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). In 1968, IOC formed an International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU). The present 25 Member States are:

Australia, Canada, Chile, China, Colombia, Cook Islands, Costa Rica, Democratic People's Republic of Korea, Ecuador, Fiji, France, Guatemala, Indonesia, Japan, Mexico, New Zealand, Nicaragua, Peru, Philippines, Republic of Korea, Singapore, Thailand, Russian Federation, United States of America, and Western Samoa.

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